BAA 05-18
Biologically-Inspired Cognitive Architectures (BICA)

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Briefing Outline

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  - Program Objective
  - Background and Motivation
  - Scope
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  - Submission Process

Defense Advanced Research Projects Agency

The Next DARPA IT Revolution: Developing Cognitive Systems

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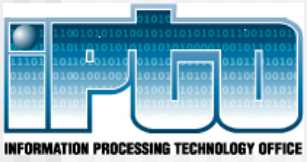
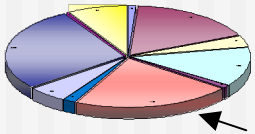


Problem and Approach

- Network-centric future depends on an absolutely dependable computational foundation
  - Computer system fragility and vulnerability are increasing; growing platform complexity undermines confidence
- Staffing for IT support is a huge, growing problem

PSAB CAOC staffing:



Communications support (~22%)

We have initiated a high-risk/high-payoff effort to make systems more responsible for their own deployment and maintenance, and more adaptable to human users

Our goal: Develop "cognitive" systems

What is a Cognitive System?

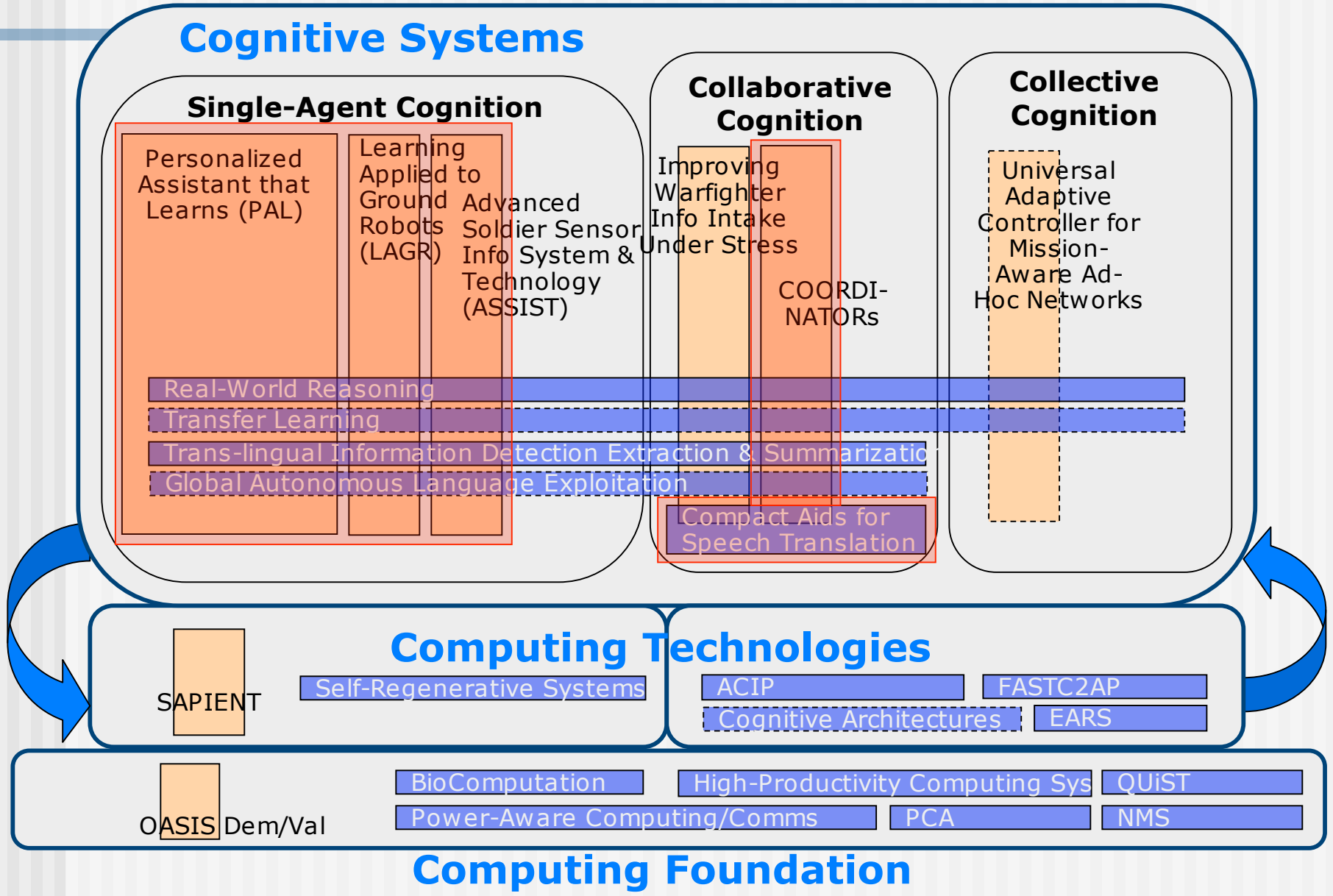
- A system that displays, in an integrated way, attributes that in humans we would consider cognitive:
  - The ability to use *knowledge* and *reason* – making explicit what is implicit in what is known
  - The capacity to *learn* – improving over time, remembering and using experience, taking advice/coaching
  - A degree of *self-awareness* and the ability to reflect on its own behavior and capabilities
  - The ability to use overtly symbolic means in *communication* with other entities

We want to create systems that truly know what they're doing

A Cognitive System can…

- …reflect on what goes wrong when an anomaly occurs and anticipate its occurrence in the future (e.g., network DDOS attack)
- …preserve corporate memory to ease transitions for rotational personnel (e.g., CAOC shift change)
- …respond to naturally-expressed user directives to change behavior or increase functionality (e.g., command situation)
- …be configured and maintained by a non-expert (e.g., on board ships, by SOF teams)
- …thwart adversarial systems that don't know what they're doing
- …last much longer than current systems and cost much less money to maintain

IPTO Program Line-up



BICA Program Objective

- To develop psychologically-based and neurobiologically-based theories, design principles, and architectures of human cognition

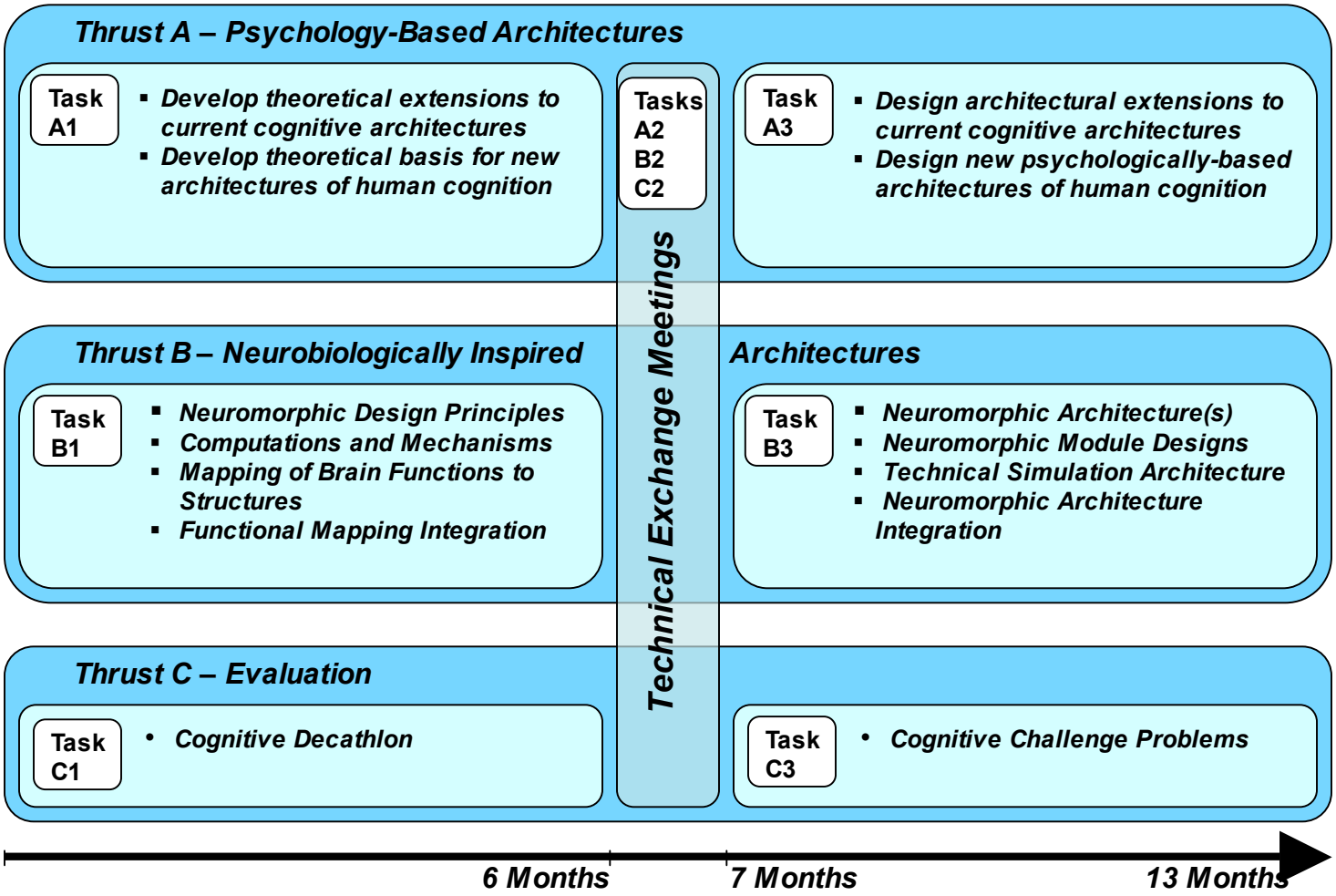
Background and Motivation

- The traditional approach to machine intelligence pursued by the Artificial Intelligence (AI) community has provided many achievements, but has fallen short of the grand vision of integrated, versatile, intelligent systems.
- Revolutionary advances may be possible by building upon new approaches inspired by cognitive psychology and neuroscience.
- Such approaches have the potential to help us understand and model significant aspects of intelligence thus far not attained by classic formal knowledge modeling technology.
- This program seeks to advance the design and development of computational models of human cognition based on architectures using both approaches.

Scope

- This program consists of 2 phases.
- This BAA is for Phase 1 only, which will span 13 months.
  - The objective for Phase 1 is to produce and assess specific cognitive architectures based on cognitive psychology and neuroscience.
  - In addition, cognitive challenge problems will be developed in Phase 1 that will be used for evaluation during Phase 2.
- The objective of Phase 2 is to implement and evaluate several of the architectures produced during Phase 1.
  - Phase 2 will be procured under a separate, future BAA.

Scope: Phase I Organization



Organization of Program Phase 1

Scope: Awards

- The dollar amount of awards will be determined by the quality of proposals and funds available. Staff years below are shown to only to illustrate the relative emphasis among the different program elements.
  - DARPA reserves the right to modify the size and composition of the Phase 1 awards, based upon the merits of the proposals received.
- Estimates by Thrust:
  - Thrust A1: 8 FTEs for 6 months
  - Thrust A3: 16 FTEs for six months
  - Thrust B1: 8 FTEs for 6 months
  - Thrust B3: 16 FTEs for six months
  - Thrust C (C1+C2): 1 or 2 contracts totaling about 4 FTEs for 13 months

Technical Approach

- **Thrust A** - this thrust seeks to make advances in the breadth and performance of cognitive models based primarily on modeling the functional psychological components of cognition.
  - Examples of such psychological components include short-term, episodic, procedural, and semantic memories.
- **Thrust B** - this thrust seeks to develop neurobiologically-inspired (neuromorphic) theories, designs, and resulting architecture(s).
  - These would include sets of neuromorphic design principles, descriptions of important neural computations and mechanisms, and a mapping of the brain's functional and representational features across its structure.
- **Thrust C** – this thrust seeks development of a framework for testing and evaluating subsequent implementations of the cognitive architectures created in Thrusts A and B. We envision the development of two test batteries:
  - a cognitive decathlon for assessing specific skills associated with cognition (e.g., visual perception, memory);
  - a set of challenge problems, each of which will require a complex range of cognitive functions in order to be successfully negotiated.

Thrust A
Psychology-Based Architectures

- It is the goal of Thrust A to design computational models of human cognition by modeling functions of the human mind
  - such as (1) perception and attention, (2) learning and memory, and (3) decision making and problem solving.
- Each functional area may be further decomposed into interrelated sub-elements
  - such as memory may be subdivided into short-term memory, episodic memory, procedural memory, and semantic memory.
- There may be separate memory components for visual and auditory imagery.
- There may be separate subsystems for language understanding and visual-spatial reasoning.

Thrust A
Psychology-Based Architectures

- **Task A1: Psychology-Based Theories of Cognition**
  - Produce psychologically-based theories of cognition covering as broad a range of cognitive activities as possible
  - It is recognized that some aspects of these initial theories may be "descriptive" rather than computational
  - Developers are encouraged to map individual cognitive functions to potential areas of the brain where such cognitive functioning is believed to occur
- **Task A2: Technical Exchange Meetings**
- **Task A3: Computational Architectures**
  - Design computational architectures that embody the theories (from Task A1) in a computational form
  - These computational architectures can be either a dramatic extension to existing architectures such as SOAR or ACT-R, or can be an entirely new approach.

Thrust B
Neurobiologically-Inspired Architectures

- Thrust B seeks a dramatic improvement in our understanding of the brain's functions and processes.
- Initially, we seek a major leap in the learning performance of traditional AI systems by augmenting and informing their designs with neuroscience principles.
- In the follow-on phase, we expect to implement a new class of *hybrid* AI systems – using a mixture of psychology-based and neuroscience-based architectures.
- Our ultimate goal is to approach brain-like performance in learning, use of experience, sensorimotor integration and other complex processes.
- At the same time we expect to develop a global theory of cognition and one or more neurobiologically-inspired, integrated cognitive architectures.
- We welcome proposals involving autonomous cognitive development.

Thrust B
Neurobiologically-Inspired Architectures

- **Task B1: Neuromorphic Theory of Cognition.**
  - The theory of cognition developed under this task will have three primary components:
    - A set of neuromorphic design principles
    - A set of descriptions of important neural computations and mechanisms
    - An allocation (mapping) of the brain's function and representational features across the brain's structure
- **Task B2: Technical Exchange Meetings**
- **Task B3: Development of Neuromorphic Architectures and Designs**
  - synthesize a neuromorphic architecture for cognitive simulation of the brain functions identified in Task B1
  - design the basic processing elements (modules) necessary to implement neuromorphic cognitive simulations which augment performance of traditional AI systems

Thrust C Evaluation Framework

- Under Thrust C, DARPA is seeking the development of an evaluation framework for the cognitive architectures developed under Thrusts A and B.
  - These evaluations will not be conducted until Phase 2 of the project, which will be covered in a separate, subsequent BAA.
  - However, we would like to develop the evaluation framework for Phase 2, as the architectures are being designed, and with interaction and dialog between the developers and the evaluator.
- We envision that two test batteries will be developed:
  - a suite of tests of individual cognitive functions (i.e., the *cognitive decathlon*)
  - a set of *challenge problems* that would require the integrated use of multiple cognitive functions.

Thrust C
Evaluation Framework

- **Task C1: Psychology-Based Theories of Cognition**
  - DARPA is seeking the development of a suite of tests (not necessarily 10) of essential cognitive functions in order to evaluate the designs of the cognitive architectures developed in Thrust A and B, during Phase 2 of the project.
  - We envision a test that will cover the major functions of human cognition: perception, attention, learning, memory, reasoning, decision-making, and problem solving
  - we envision a suite of tests that would be implemented in a simulation environment, cover the range of major functions of human cognition, and require the cognitive models under test to provide a relatively unified and complete set of cognitive components
- **Task C2: Technical Exchange Meetings**
- **Task C3: Challenge Problem Set**
  - create challenges problems relevant to military situations that must be progressively more challenging, and involve both embedded and non-embedded problems

Submission Process

- Proposers must submit the original and 2 copies (3 total) of the full proposal and 2 electronic copies (i.e., 2 separate disks) of the full proposal
- The full proposal (original and designated number of hard and electronic copies) must be submitted in time to reach DARPA by 12:00 PM (ET) Mar 1, 2005, in order to be considered during the initial evaluation phase.
- However, BAA 05-18 will remain open until 12:00 NOON (ET) Jan 17, 2006.
  - Thus, proposals may be submitted at any time from issuance of this BAA through Jan 15, 2006.
  - While the proposals submitted after the Mar 1, 2005 deadline will be evaluated by the Government, proposers should keep in mind that the likelihood of funding such proposals is less than for those proposals submitted in connection with the initial evaluation and award schedule.

Biologically-Inspired Cognitive Architectures

Questions?